New instrumentation for optical beam diagnostics

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on behalf of teams from

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Moscow, Russia

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Институт Ядерной Физики СО РАН
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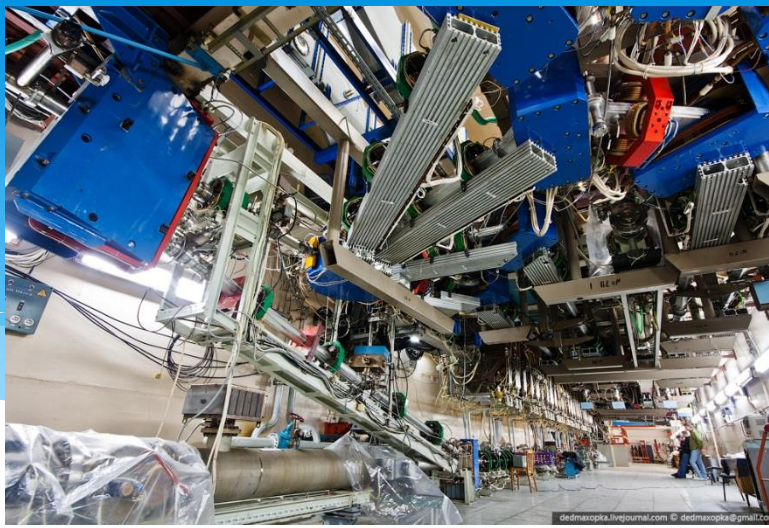
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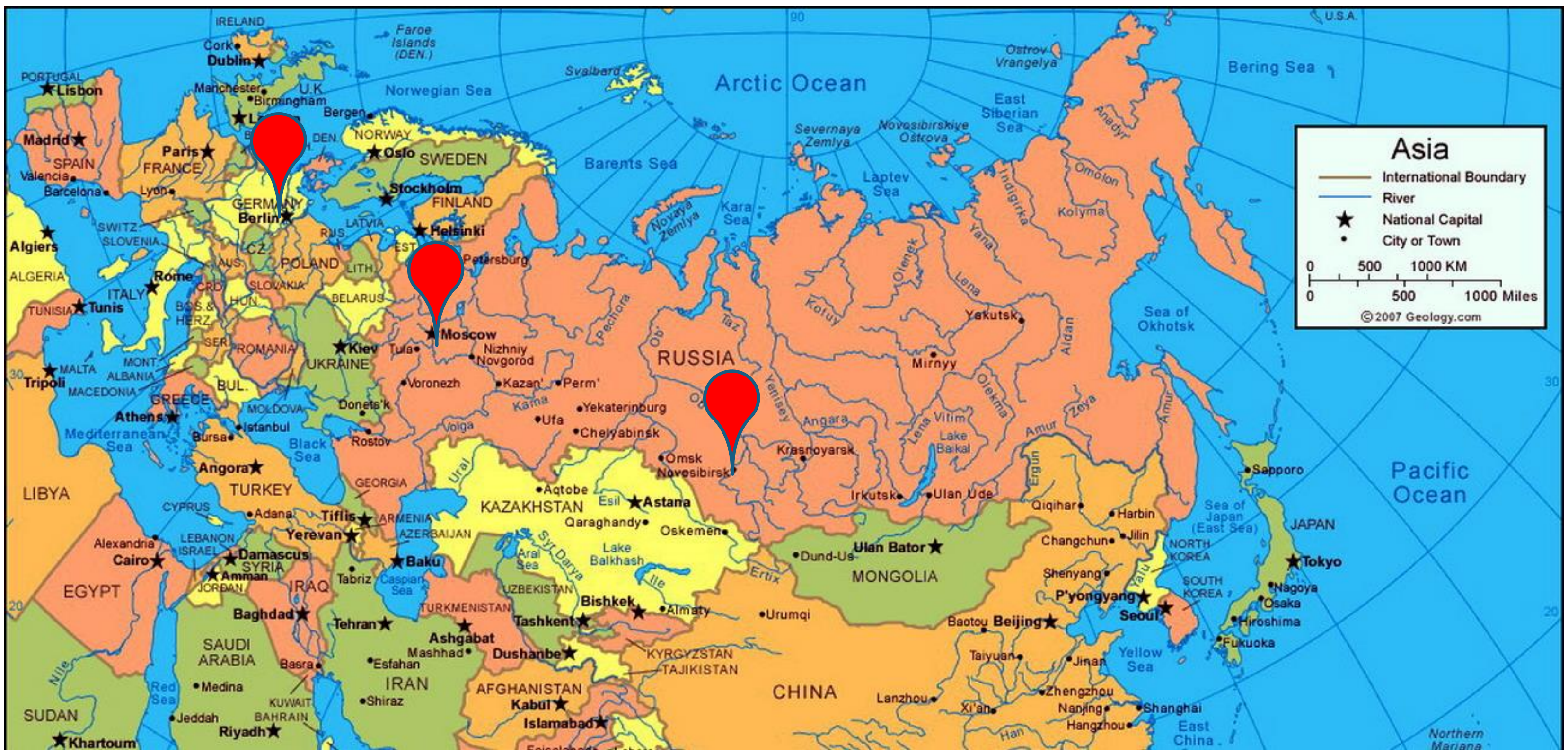
Asia
International Boundary
River
National Capital
City or Town
0 500 1000 KM
0 500 1000 Miles
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Arctic Ocean
Pacific Ocean
Bering Sea
Norwegian Sea
Barents Sea
Kara Sea
Laptev Sea
East Siberian Sea
Sea of Okhotsk
Sea of Japan (East Sea)
Yellow Sea
East China
Black Sea
Caspian Sea
Aral Sea
Mediterranean Sea
Red Sea
Faroe Islands (DEN.)
Svalbard
Severnaya Zemlya
Novosibirskiye Ostrova
Ostrov Vrangelya
Novaya Zemlya
RUSSIA
CHINA
MONGOLIA
KAZAKHSTAN
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NORTH KOREA
SOUTH KOREA
TURKEY
IRAN
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SYRIA
SAUDI ARABIA
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AFGHANISTAN
TURKMENISTAN
UZBEKISTAN
KYRGYZSTAN
TAJIKISTAN
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Omsk
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Irkutsk
Ulan Ude
Yakutsk
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Nizhniy Novgorod
Kazan'
Perm'
Yekaterinburg
Chelyabinsk
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Voronezh
Tula
Rostov
Aqtobe
Astana
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Oskemen
Almaty
Bishkek
Tashkent
Dushanbe
Ashgabat
Kabul
Islamabad
Tehran
Baghdad
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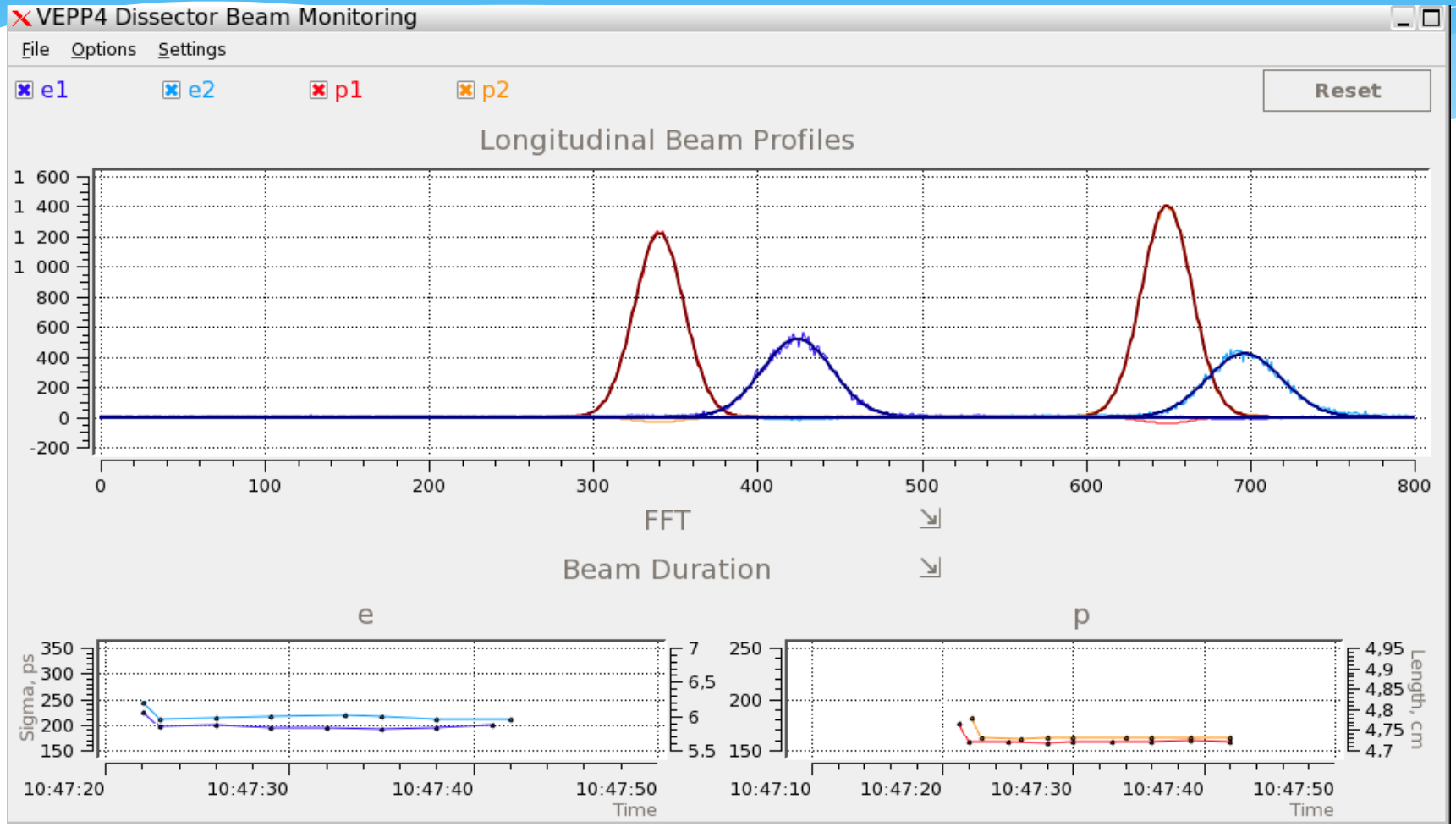
Damascus
Cairo
Riyadh
Khartoum

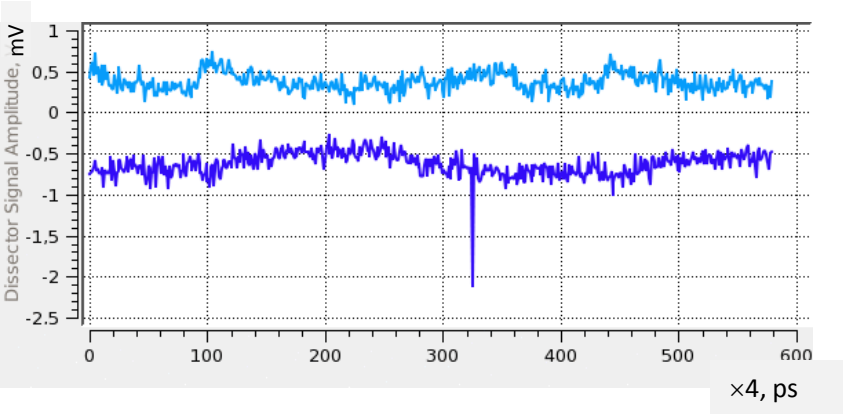
Injection Complex VEPP-5 providing both BINP colliders VEPP4M and VEPP-2000 with the electron and positron beams

Parameters (2016): Energy: **395 MeV**
Storage rate e^- @ 12.5 Hz: **$4.0 \cdot 10^{10}$/s** (70 mA/s)
Storage rate e^+ @ 12.5 Hz: **$4.0 \cdot 10^{9}$/s** (7 mA/s)
Max. beam current e^- : **100 mA, $4.2 \cdot 10^{10}$ particles**
Max. beam current e^+ : **70 mA, $2.9 \cdot 10^{10}$ particles**

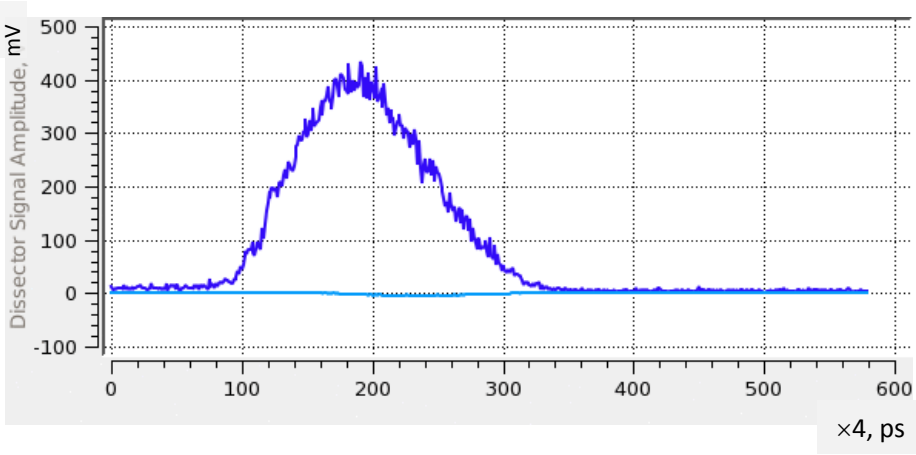
The software for processing of the dissector signals



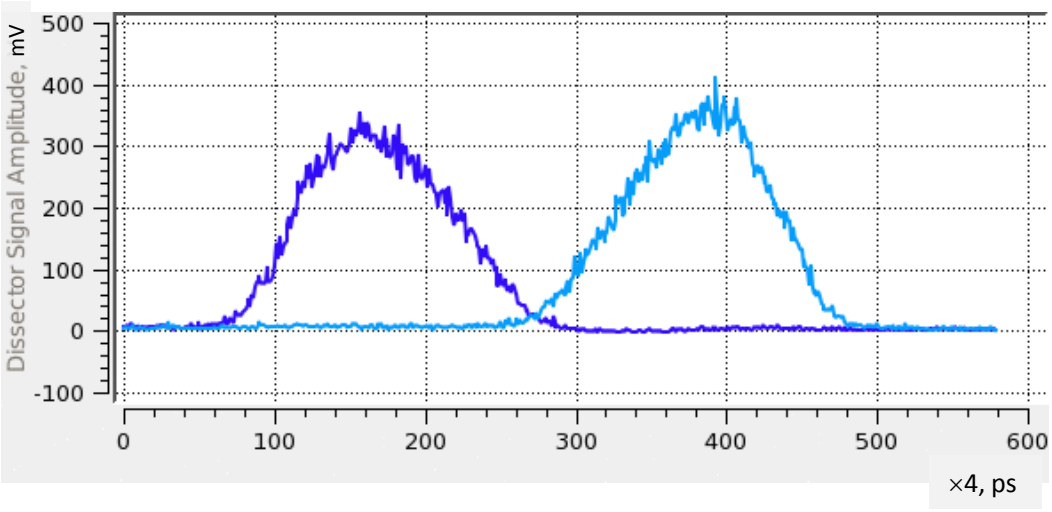
The behavior of the longitudinal profiles of the bunches during beam storage and acceleration in the VEPP-3 (the booster of the VEPP-4M collider)



The storage of the beam in the booster at the energy E = 354 MeV



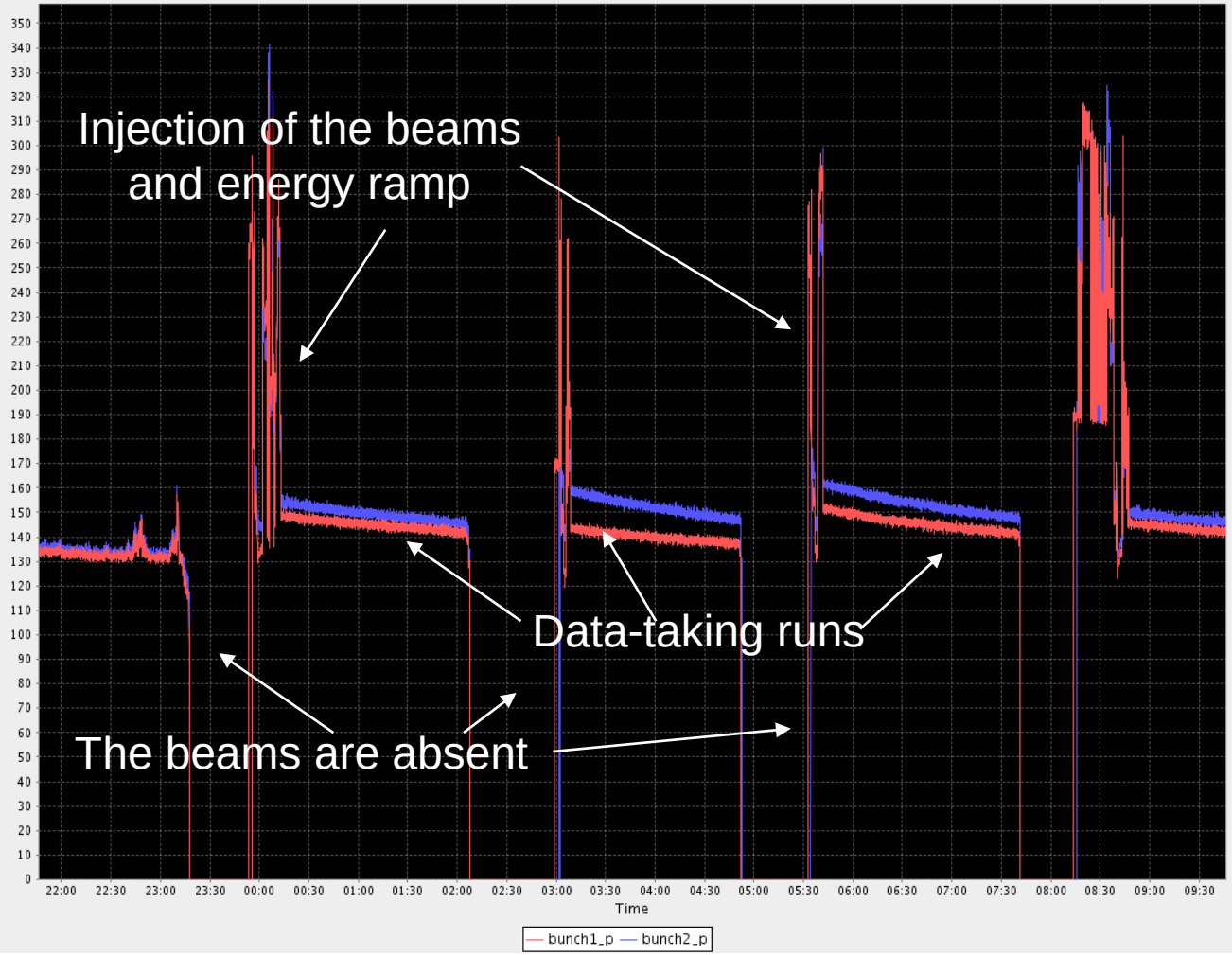
The phase oscillations of the bunches during storage process



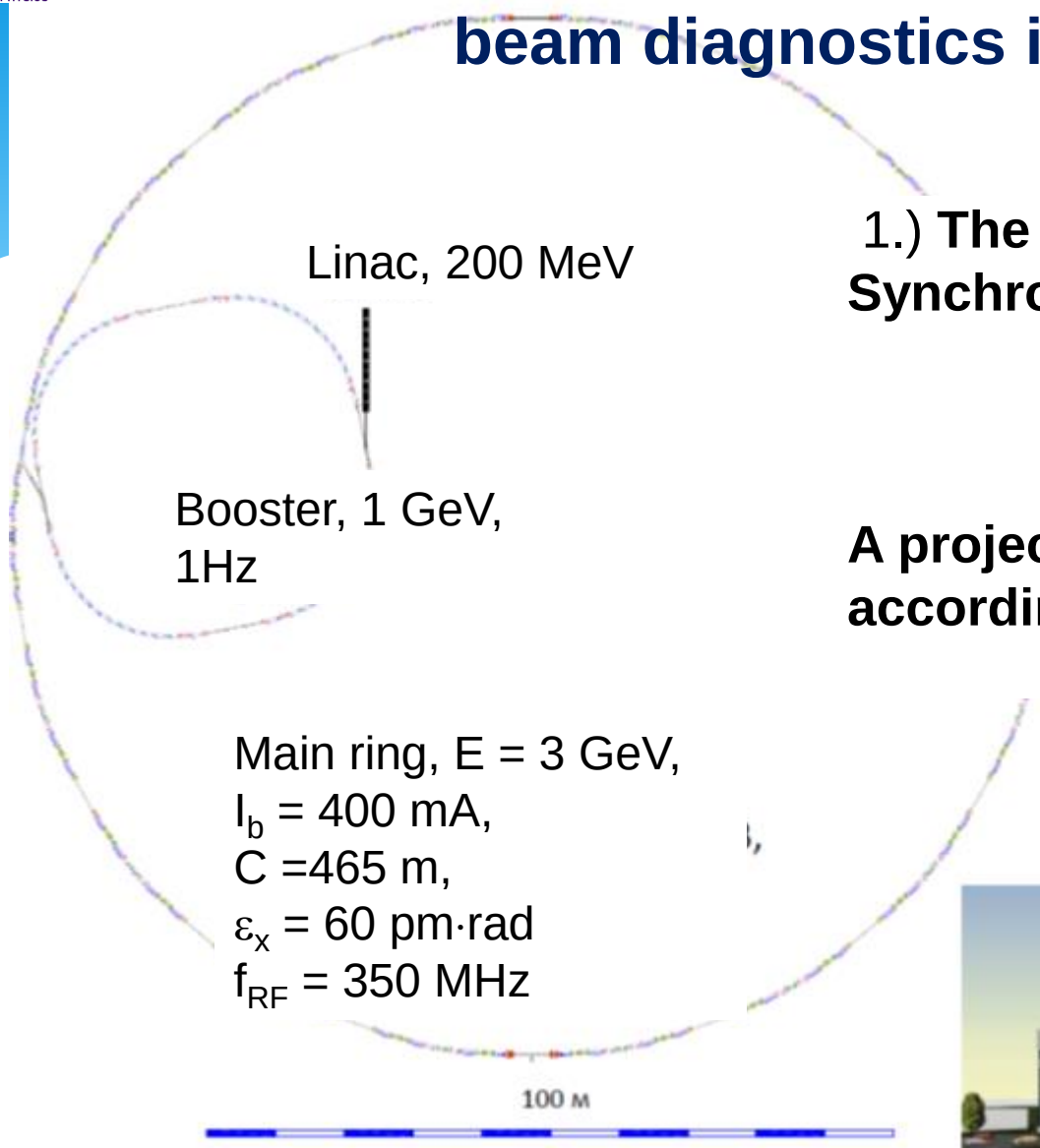
The acceleration of the beam to E = 1892 MeV. The acceleration frequency switches from 8 MHz to 72 MHz at the E = 600 MeV. It leads to well-seen decrease of the bunches length.

The repetition rate (slow scan frequency) is 50 Hz

The record of positron bunches lengths, saved in the data base of the VEPP-4M during 12-hours shift



The very new two reasons to develop this kind of the beam diagnostics in the BINP

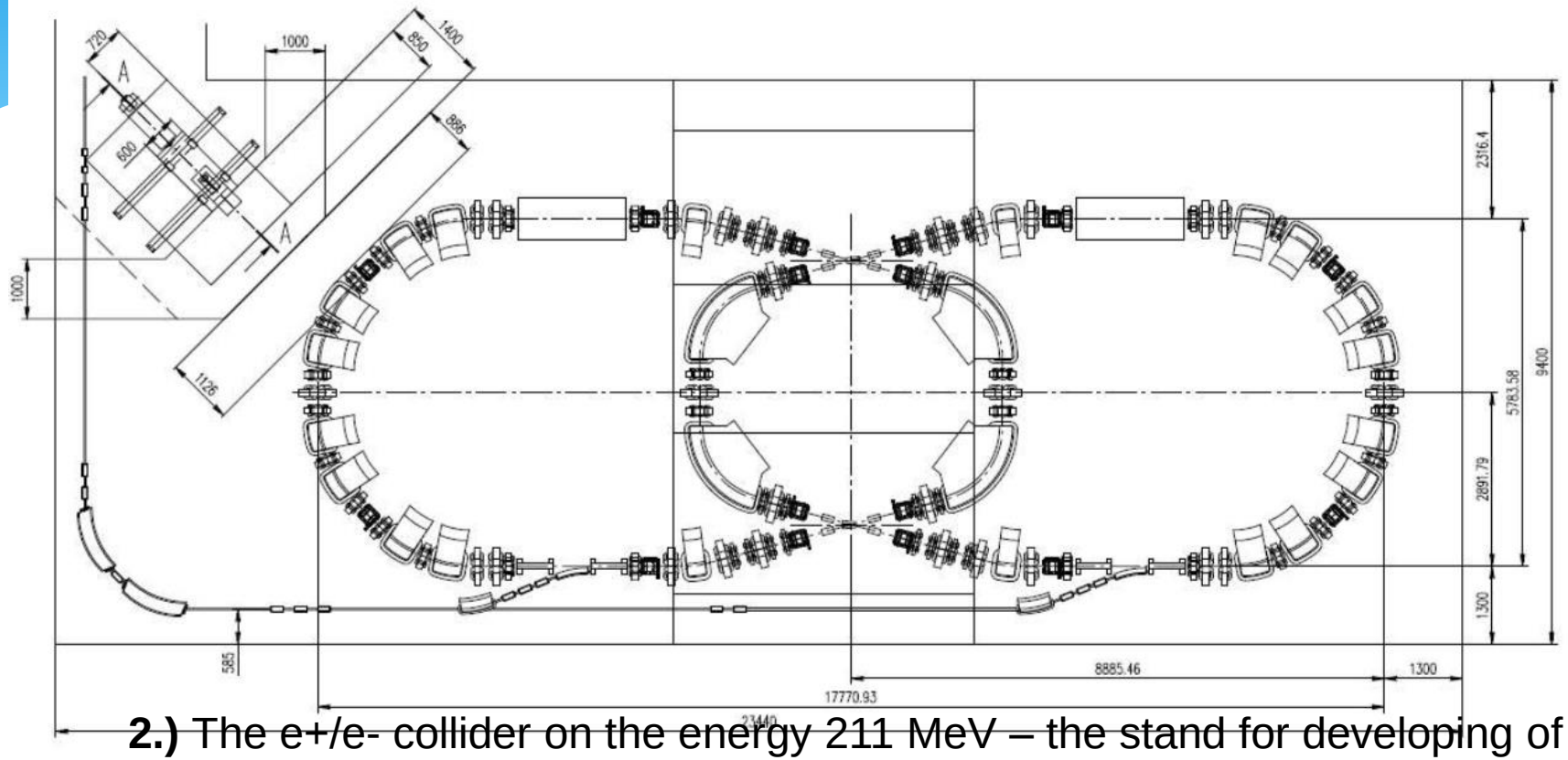


1.) **The 3rd generation Synchrotron Radiation Source.**

«SKIF» (СКИФ)

A project financing develops in according with a road map.

The very new two reasons to develop this kind of the beam diagnostics in the BINP

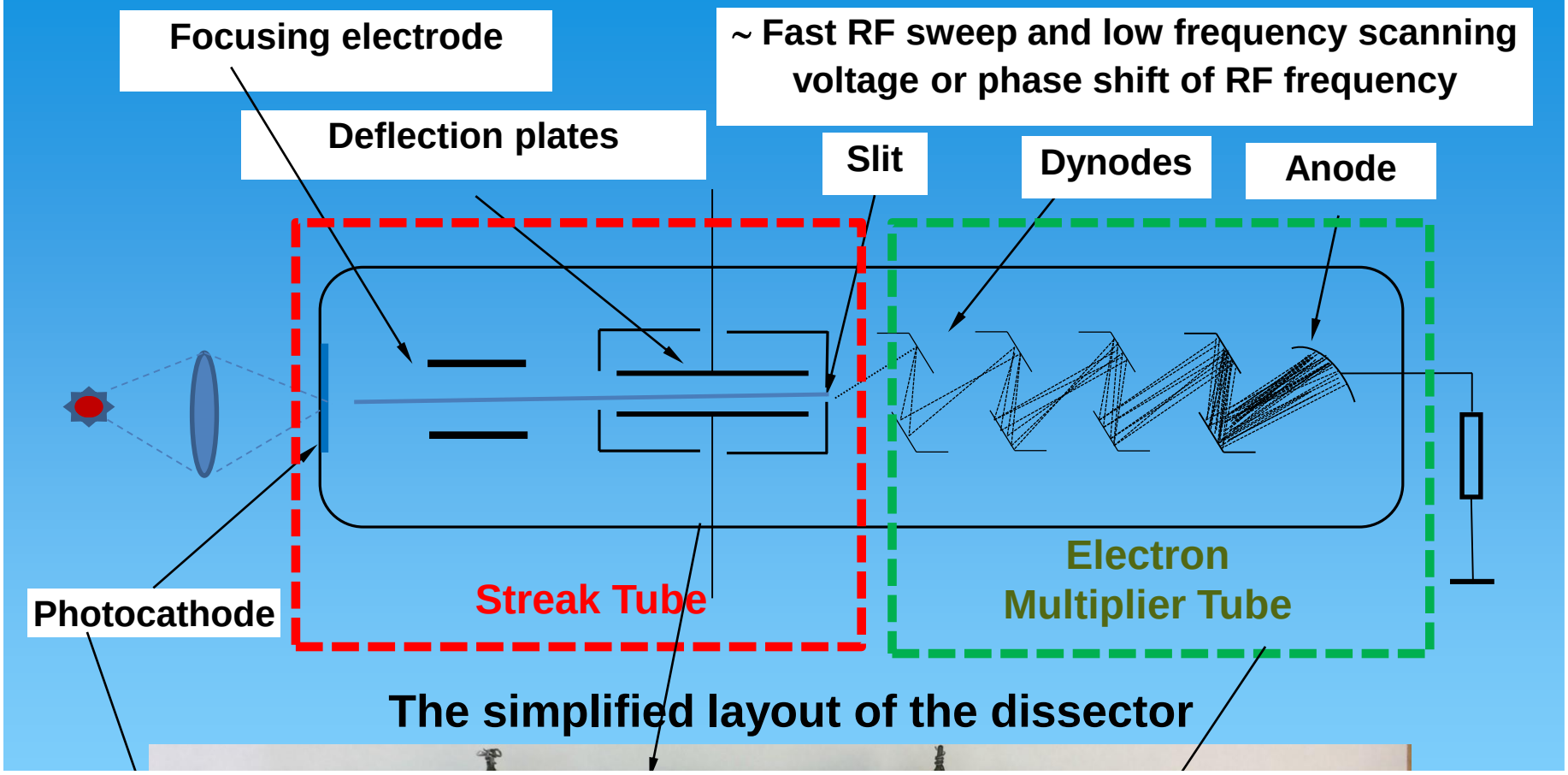


2.) The e+/e- collider on the energy 211 MeV – the stand for developing of technologies which BINP must have if going to build the super cτ-factory.

The scientific goal of the installation is a search of μ+μ- atoms.

The project is approved by Ministry of Science and Education of RF and got a restricted financial support.

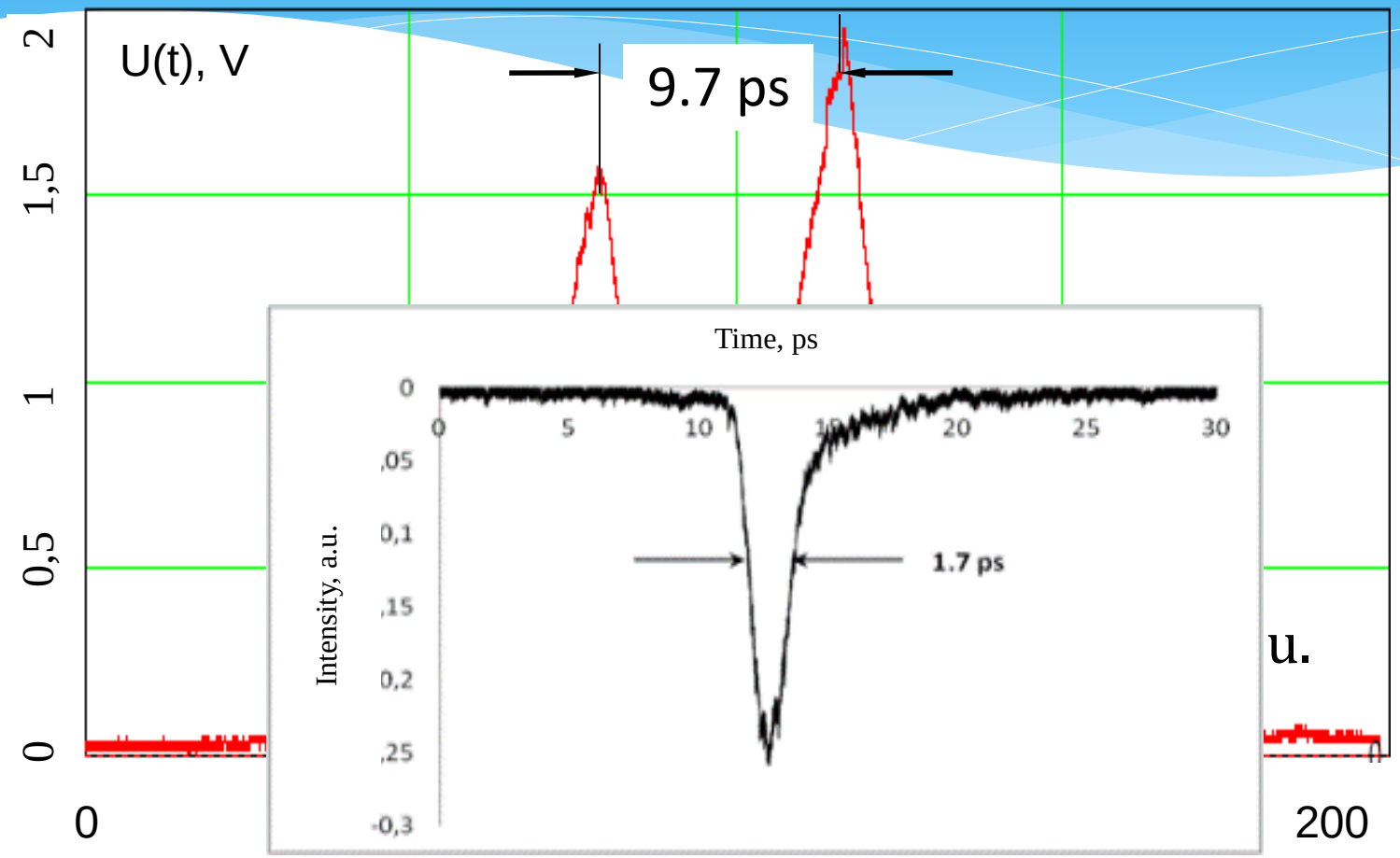
Streak Camera transformed into Dissector



The simplified layout of the dissector

The last version of the device was created in cooperation between BINP and Prokhorov Institute of General Physics (Moscow). The “head” of the streak-tube PIF-1/S20(S1) was combined with an Electron Multiplier Tube. The streak-tube has a temporal resolution about 1 ps and we hope to get the same value for the dissector

The two laser pulses separated by a 10-ps time interval, which were recorded by the dissector.

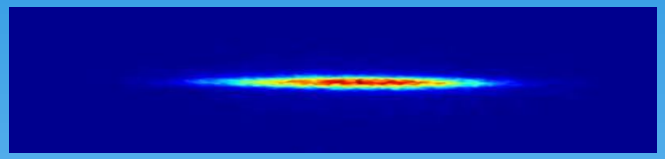


Very recently we have achieved the temporal resolution of 1.7 ps.

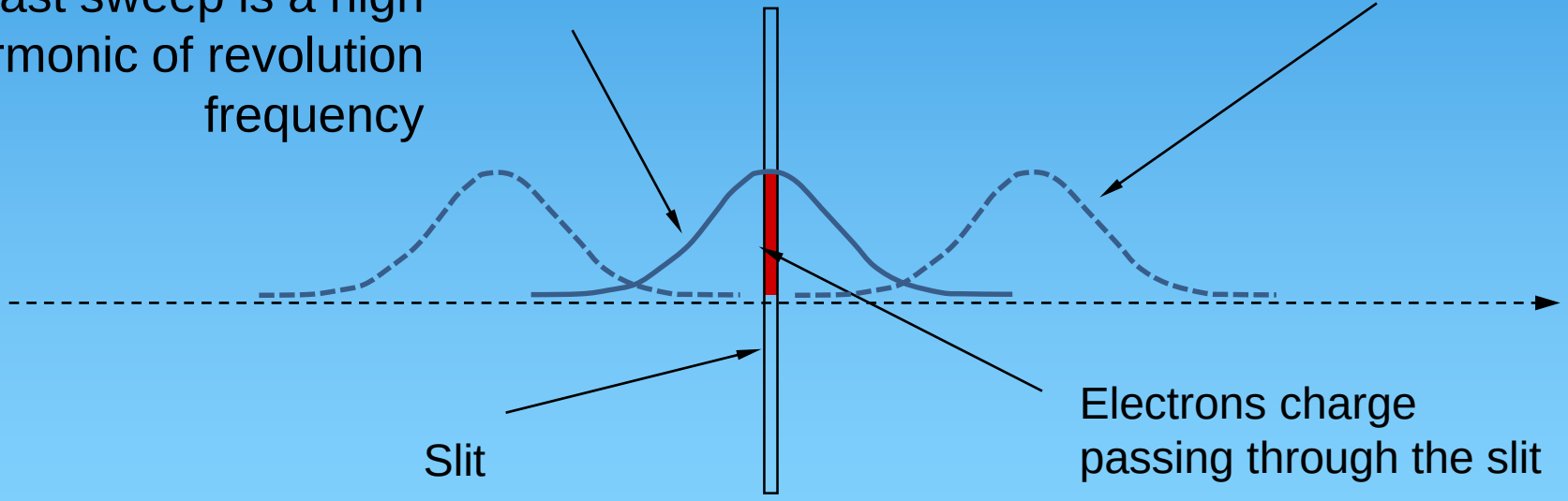
Streak Camera transformed into Dissector

Beam longitudinal profile *Q(x)* obtained at the slit aperture with RF fast sweep

A frequency of the RF fast sweep is a high harmonic of revolution frequency

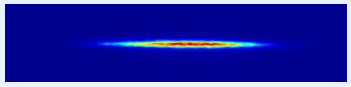
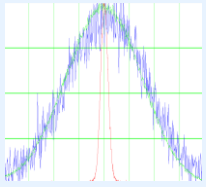


Slow scanning of the beam longitudinal profile across the slit



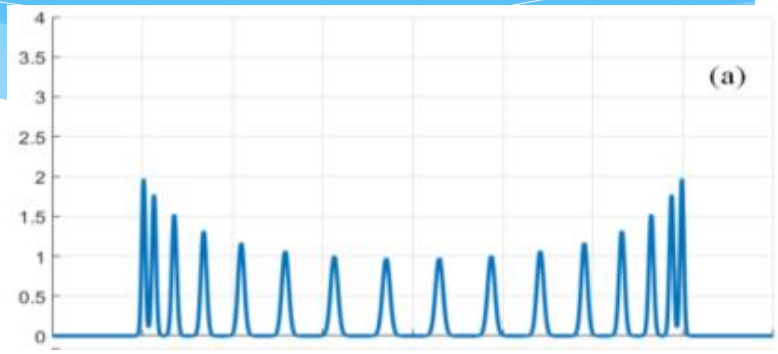
The electrons passing through the slit are amplified by the Electron Multiplier Tube. The anode signal of the EMT is recorded by the ADC

A comparison of the mode of operation of streak camera and dissector

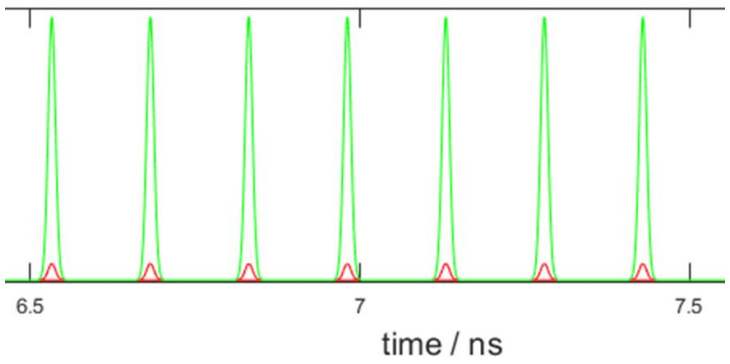
Parameter	Streak camera	Dissector
Sweep	Linear ramped voltage	RF frequency
Output signal	Image 	Electric pulse 
Acquired events	Single	Periodical; The final profile is an average of many events

Two ways of slow scanning of the charge distribution on the slit plane of the dissector

1. Slow linear ramp of the voltage which is additionally applied to the deflector plates. The scale of the dissector is non-linear:



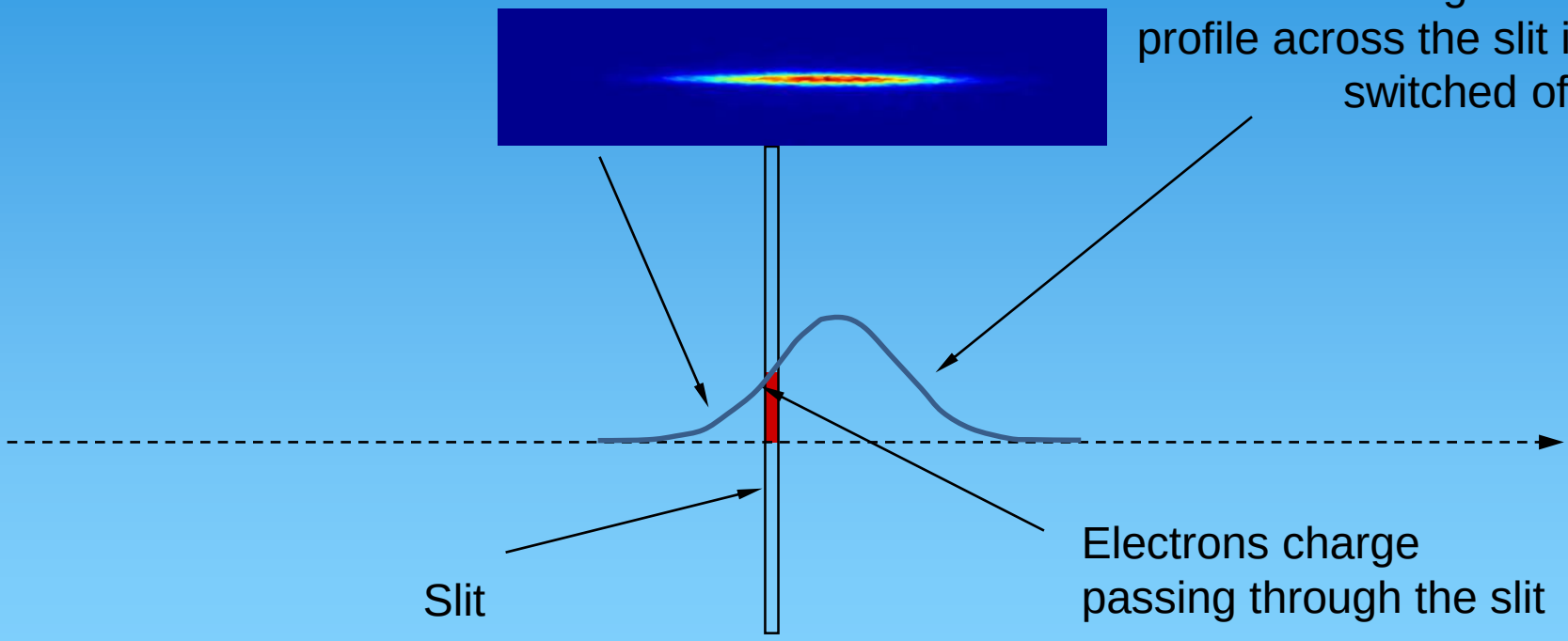
2. The scanning by the slow shift of the HF voltage applied to the deflecting plates. The scale of the dissector is linear:



Each approach has advantages and disadvantages. Most likely, we will combine both of them.

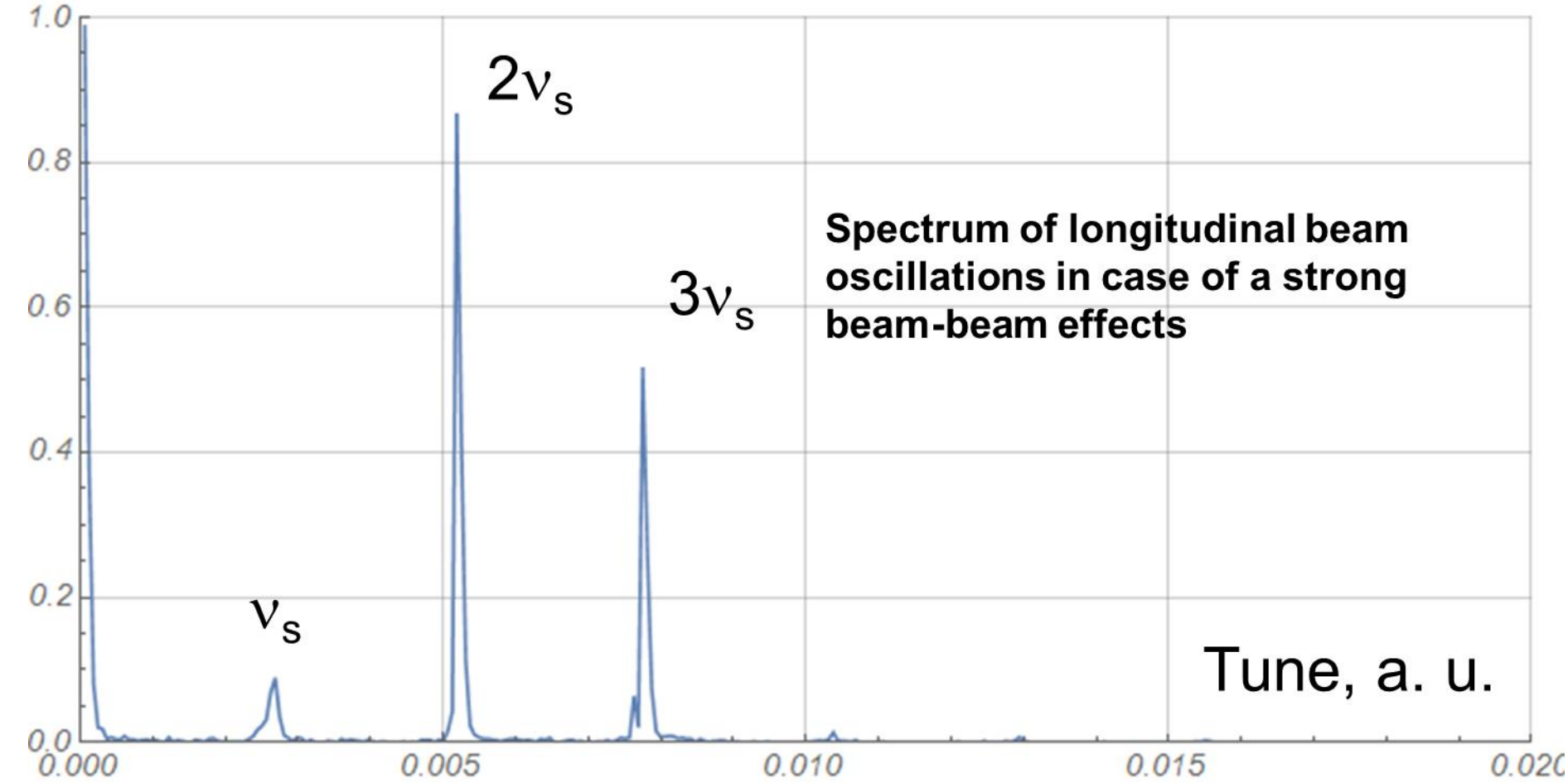
Dissector operating in the mode of «phase slit»

Beam longitudinal profile *Q(x)* obtained at the slit aperture with RF fast sweep



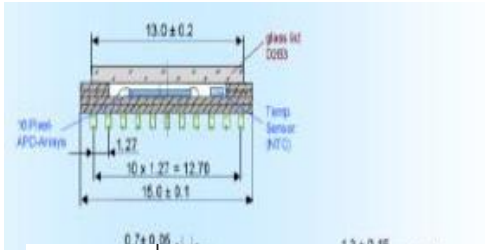
The dissector records the dipole oscillations of the beam and any distortions on the longitudinal profile of the beam at the point of a beam profile, which was placed on the slit.

Beam-Beam effects (VEPP-2000)



Spectrum of longitudinal beam oscillations in case of a strong beam-beam effects

THE APD BASED OPTICAL DEVICE
FOR TURN TO TURN BEAM PROFILE MEASUREMENT



P

Channel

Center of the beam

σ_x of the beam

Turn number

0
2
4
6
8
10
12

0
500
1000
1500
2000
2500

Rapid development of CMOS cameras

Margie P. Olbinado; Alexander Rack

Proc. SPIE 11051, *Recent advances on in situ materials characterization using ultra high-speed x-ray imaging at The European Synchrotron* – ESRF , 110510F (28 January 2019); doi: 10.1117/12.2524607

Shimadzu Ltd (Japan) Hypervision HPV-X2

FTCMOS camera

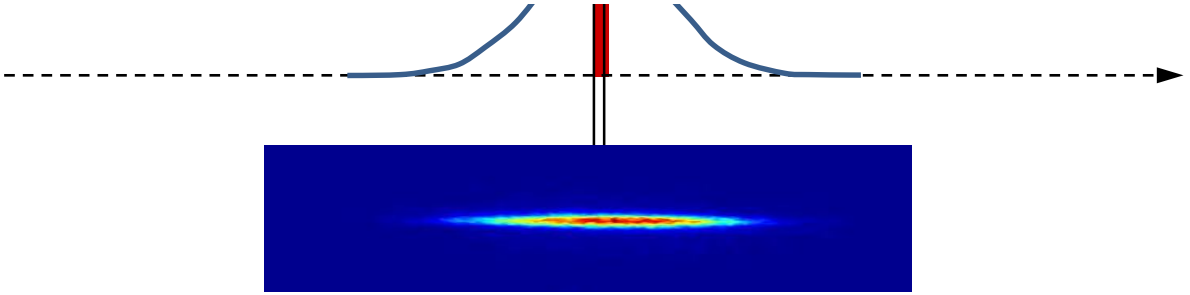
32 µm pixels (30 µm × 21.3 µm active)
400 x 256 (250 effective) pixels
128 frames per recording (full resolution)
256 frames per recording (half resolution)

60 fps to 2 Mfps, interval of 1/10 ns
Fixed 5 Mfps (full resolution)
Fixed 10 Mfps (half resolution)
Triggerable but no synchronization

Some problems with multi-bunched beam….

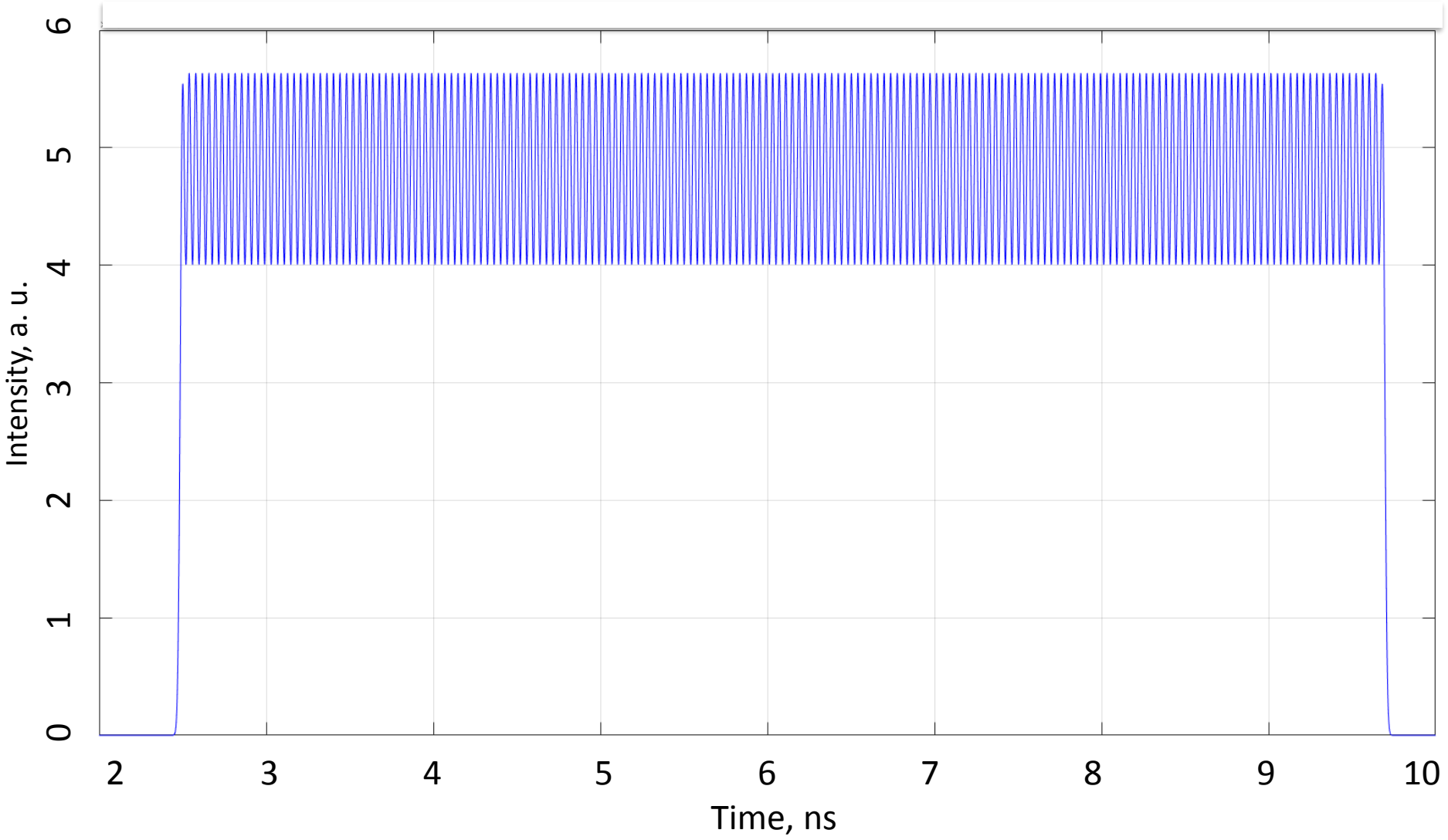
The goal is to select and measure the longitudinal profile of the given bunch in the beam

- **The high amplitude of the RF voltage applied to the deflecting plates of the dissector is provided by the resonance circuit. The cut-off frequency of the circuit determined by the design of the dissector is about $f_d \approx 350$ MHz**
- **We have a good experience with the dissector performance at $f_D \approx 100$ MHz. Very likely, it is possible to reach $f_D = 300$ MHz.**

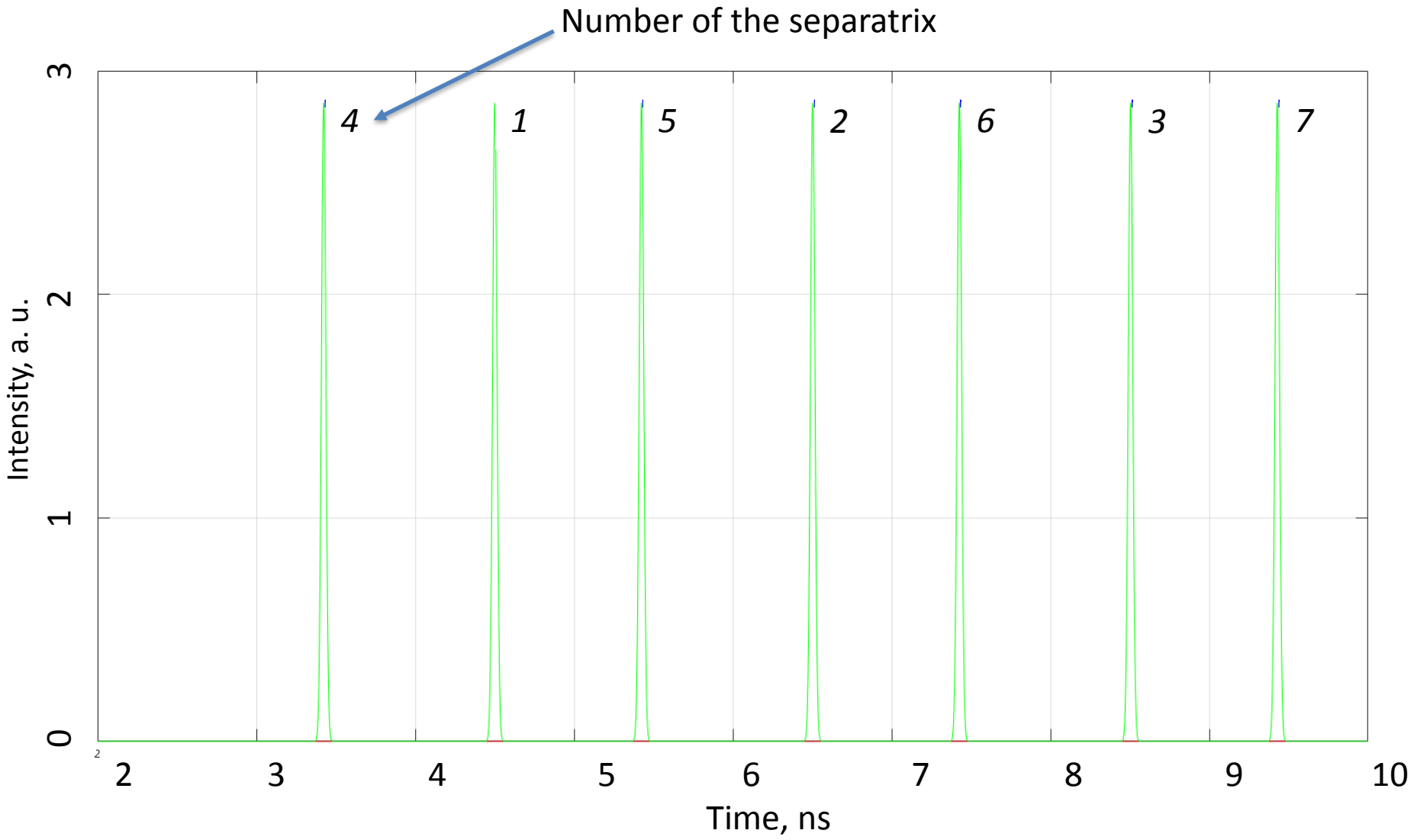


Bunches distribution on the slit plane of the dissector for ANKA, f_D = 46 harmonics of revolution frequency

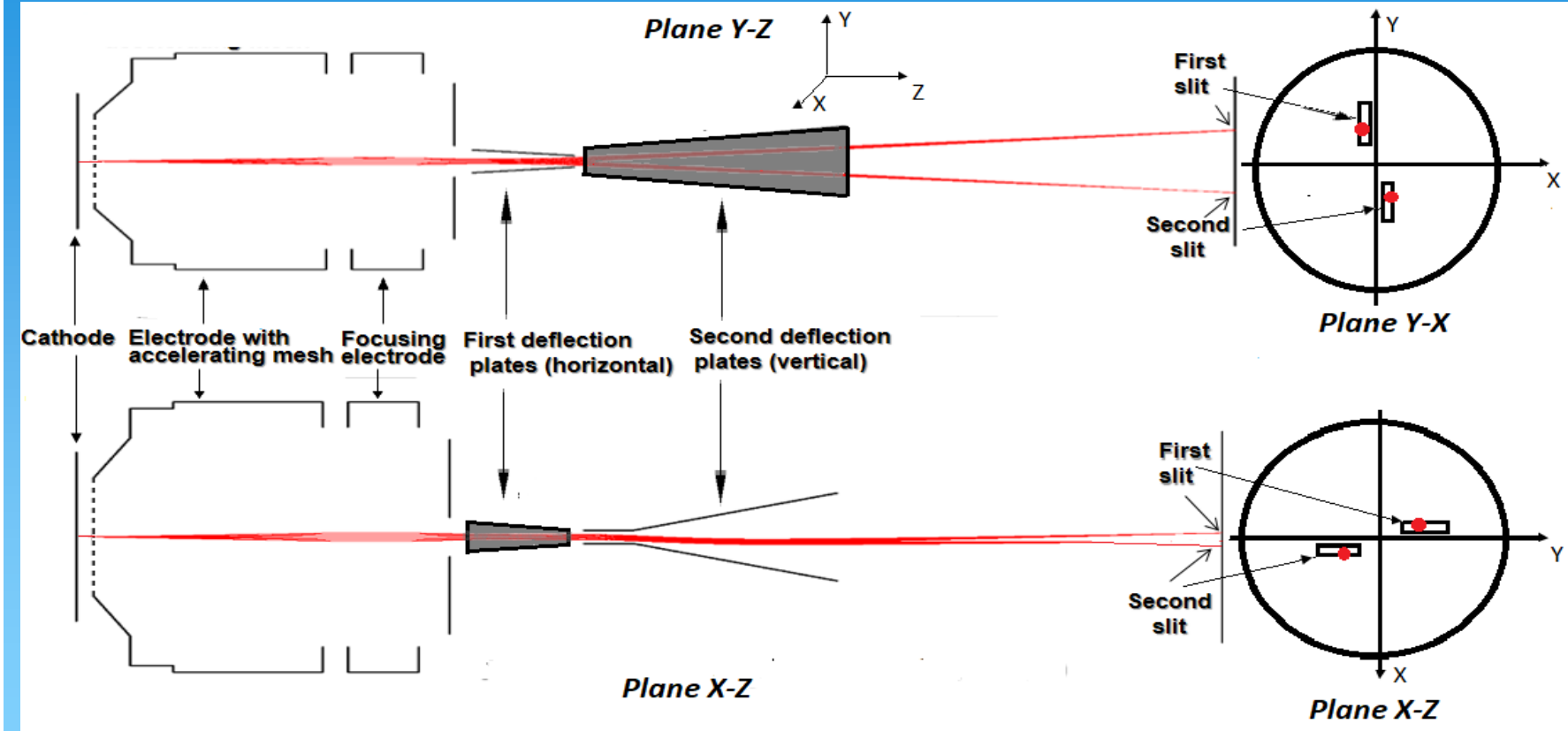
Bunches distribution on the slit plane of the dissector for ANKA, f_D = 47 harmonics of revolution frequency



Bunches distribution on the slit plane of the dissector for ANKA, f_D = 46 harmonics of revolution frequency

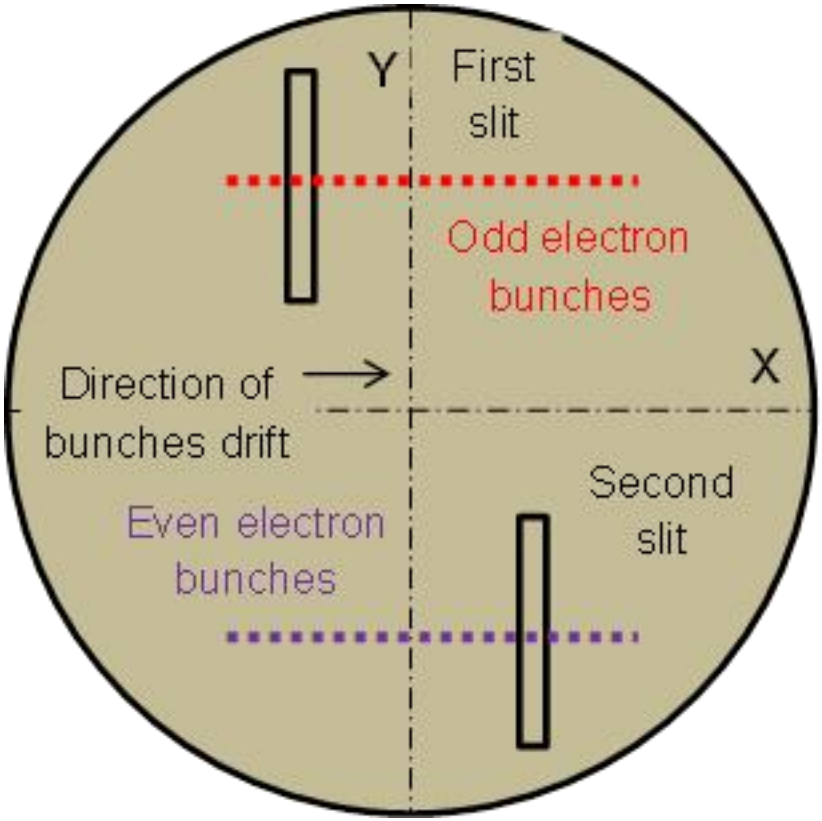


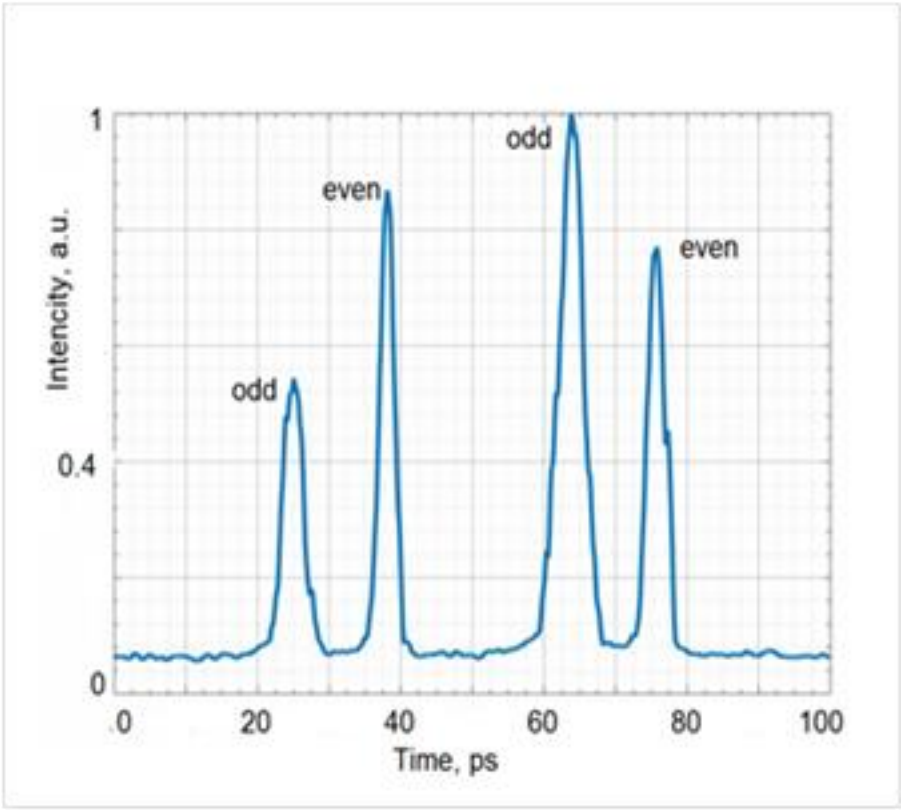
Trajectories of the electron bunches deflected by first deflection plates and swept by second deflection plates in two mutually perpendicular planes.



The sweep frequencies on the plates relates as 1:2

The separation of the bunches in the baffle plate of the dissector with the crossed sweep

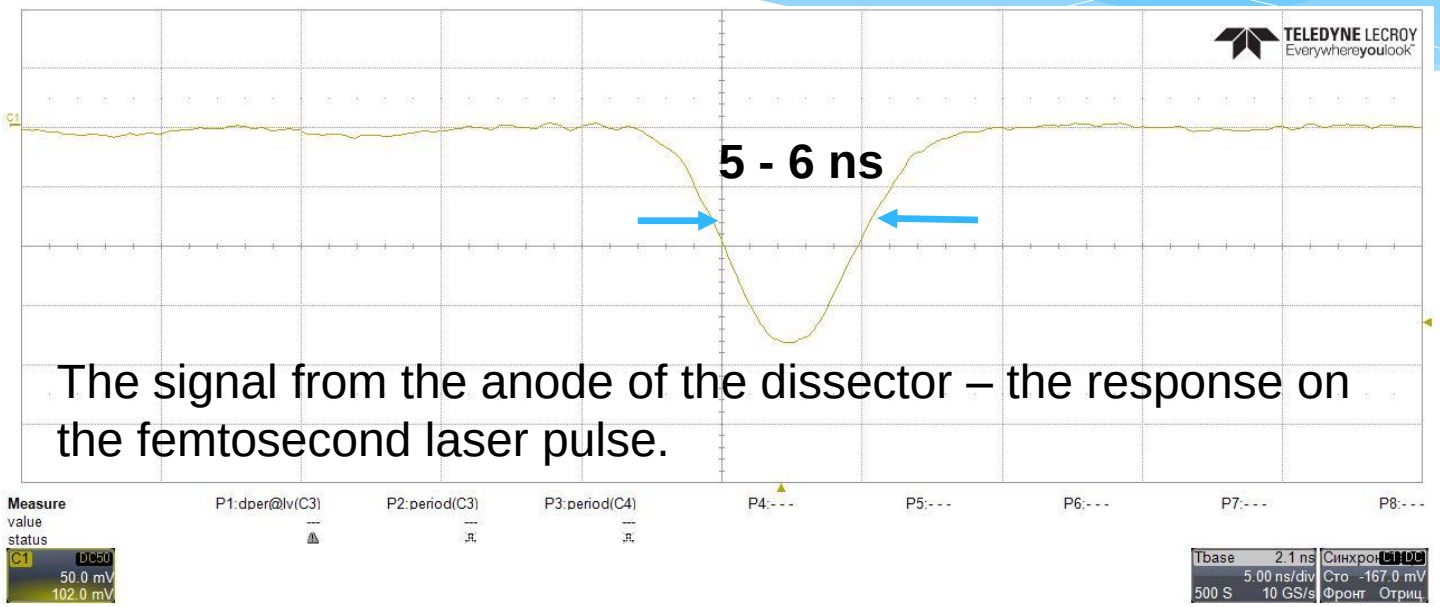




Left: the movement of the electron beam on the baffle plate.

Right: the laser pulses acquired in the proof-of-principle experiment.

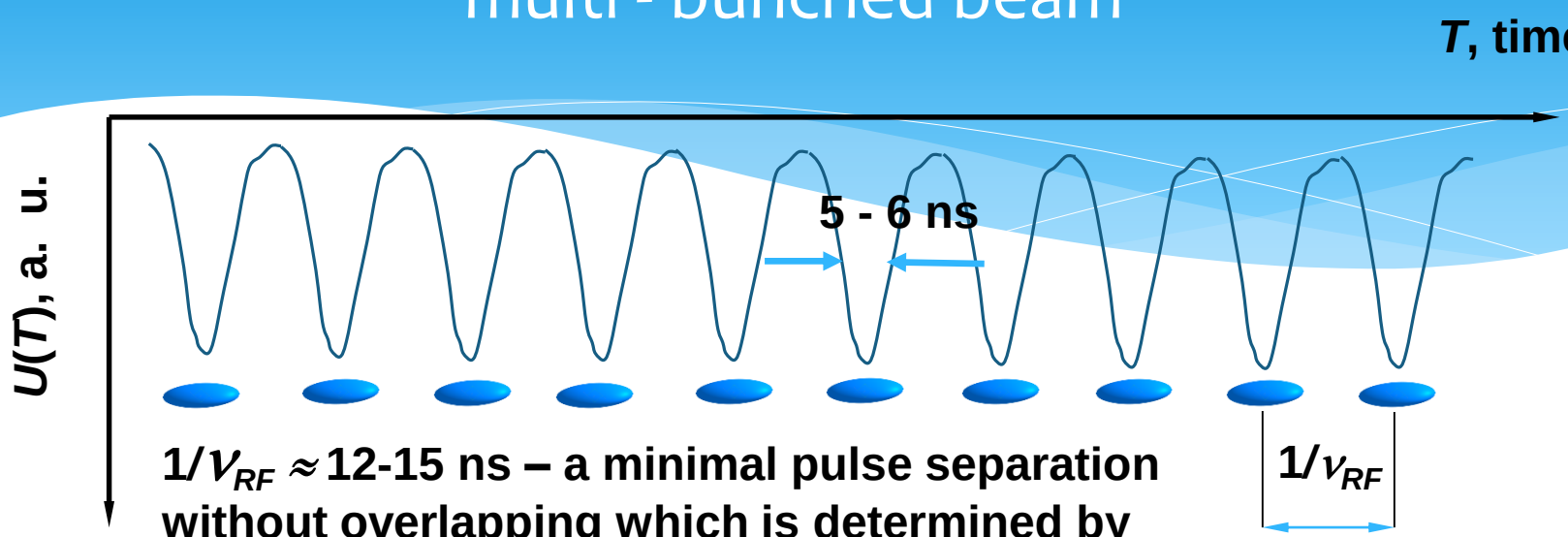
The multi-bunched mode of the dissector operation. How to measure a length of the each bunch in the beam?



The signal from the anode of the dissector – the response on the femtosecond laser pulse.

We can select the bunch in the beam using the temporal resolution of the EMT. The response of the dissector on the single SR pulse is presented in the Figure.

The signal rom the anode of the dissector from the multi - bunched beam



$1/\nu_{RF} \approx$ 12-15 ns – a minimal pulse separation without overlapping which is determined by the temporal resolution of the EMT of the dissector.

We have to «thin out» the pulses at the enter of the EMT before to select a given bunch of the beam on the exit of the device. The design of the dissector allows us to do that with the pulse with moderate parameters:

duration $\tau \approx$ 20 ns, amplitude $U \approx$ 30 V

The nearest plans

* We want to get an experience with sweep frequency of 181 MHz (accelerating frequency of the VEPP-4M) at the VEPP-4M collider.
* The operation of the dissector in multi-bunched mode can be tested at the Siberia-2 storage ring (Moscow). This accelerator has 75 bunches in the beam and the same RF frequency as the VEPP-4M has.

Conclusion

- BINP and IGP develop the diagnostics which potentially allows permanently measure the longitudinal profile of the selected bunch in a multi-bunched beam in circular accelerators .